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[54] **COMMUNICATION WITH REENTRY VEHICLE THROUGH MODULATED PLASMA**

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[51] **Int. Cl.**[6] **H01Q 1/28**

[52] **U.S. Cl.** **343/705**; 343/708

[58] **Field of Search** 343/708, 705, 872

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,583,540	1/1952	Bennett	343/705
3,566,235	2/1971	Rose	343/705 X
3,568,202	3/1971	Filton	343/709
3,846,798	11/1974	Cal	343/705
4,509,709	4/1985	Uttan et al.	343/705 X
4,922,259	5/1990	Hall et al.	343/700 MS
5,315,309	5/1994	Rudow et al.	343/708 X

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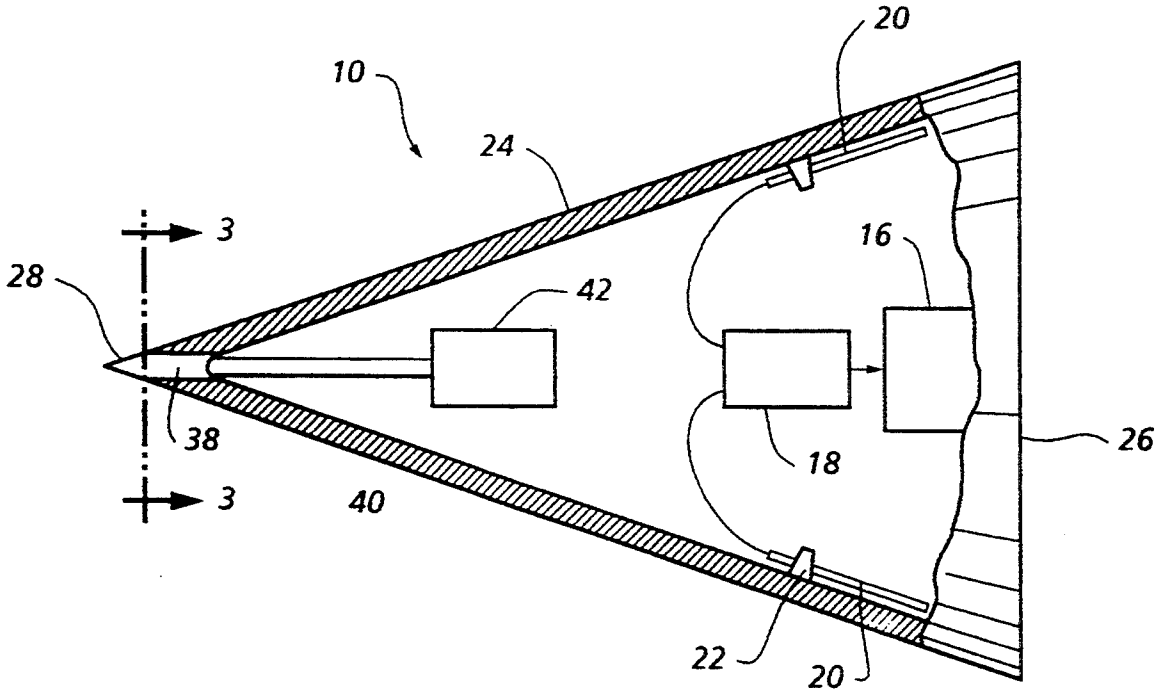
[57] **ABSTRACT**

Signal antennae are mounted on the casing wall between forward nose and rear tail ends of an aerospace launched vehicle for radio communication through a radiation conducting sheath of plasma formed thereon by atmospheric ionization during descent of the vehicle along a non-gliding reentry path. The reentry path is maintained by vehicle guidance at a steep angle in response to data transmitted to the antennae through the radiation conducting sheath having a plasma content minimized by cooling which is thereby maintained in complete surrounding relation to the vehicle and modulated to enhance data transmission during the entire duration of vehicle descent.

8 Claims, 2 Drawing Sheets



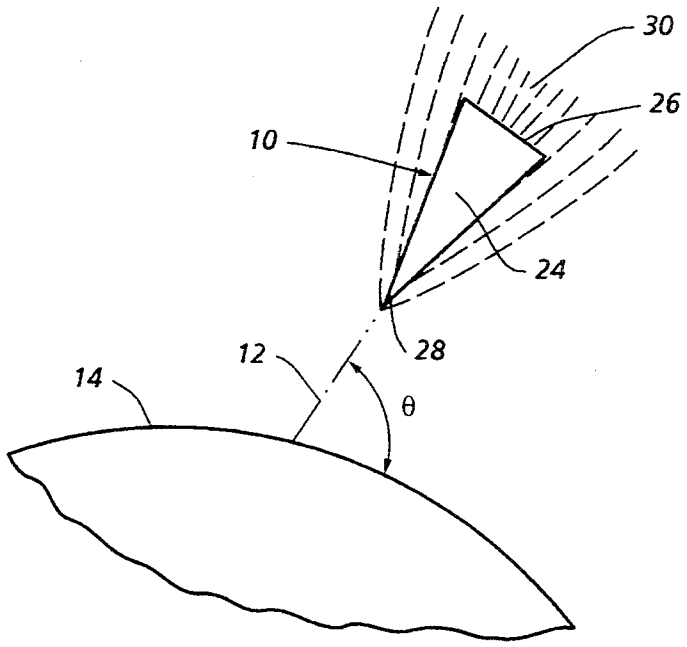


FIG. 1

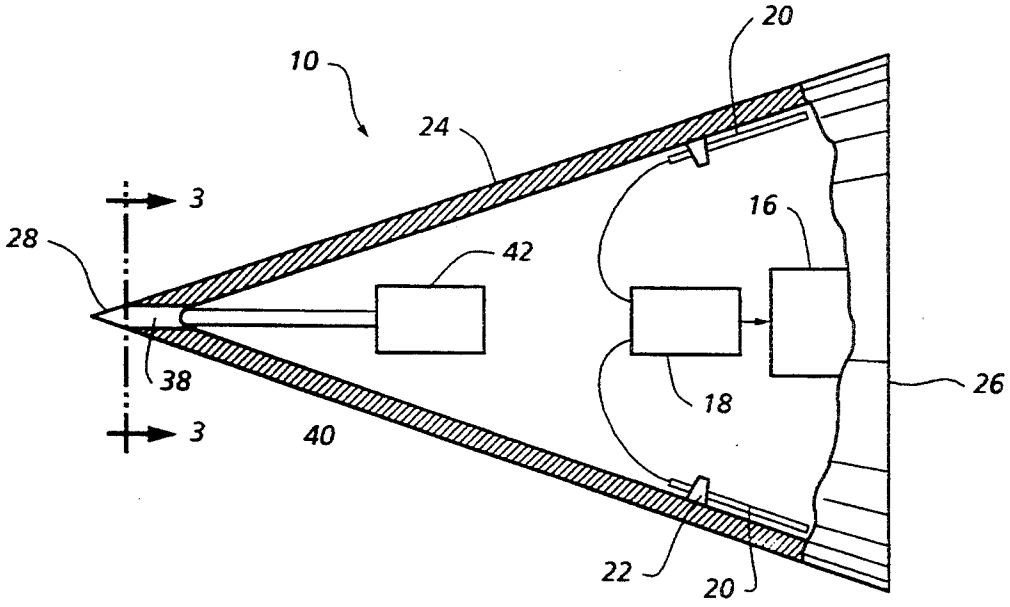


FIG. 2

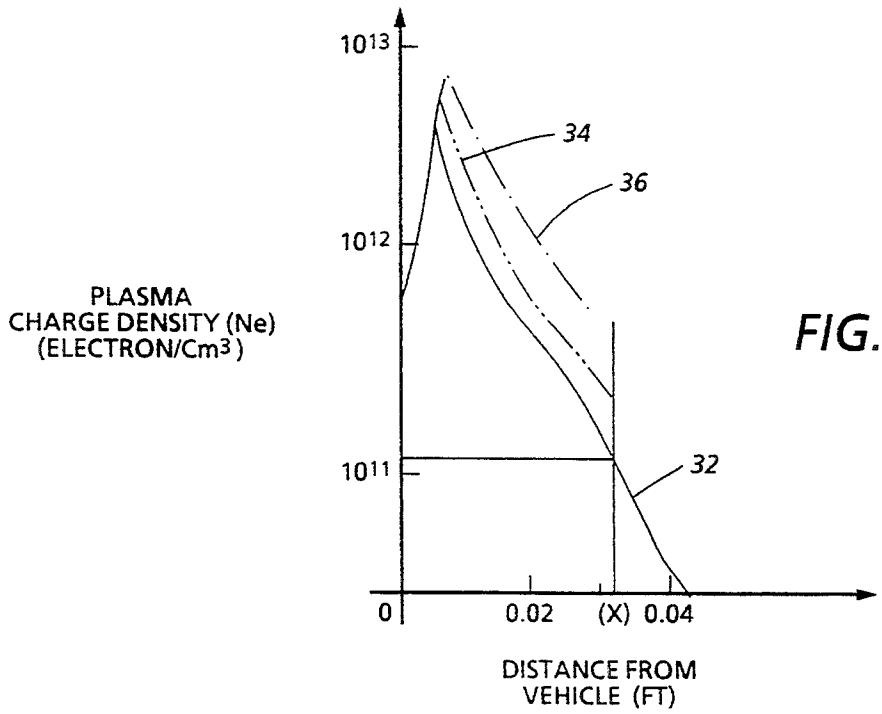


FIG. 4

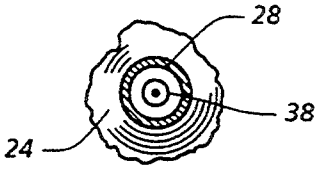


FIG. 3

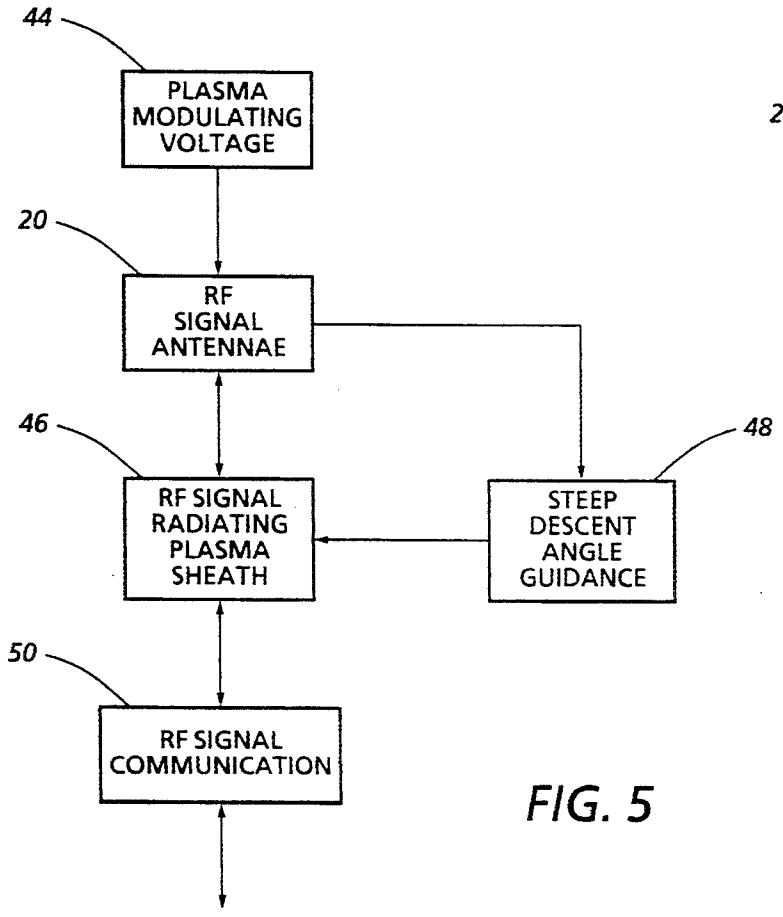


FIG. 5

COMMUNICATION WITH REENTRY VEHICLE THROUGH MODULATED PLASMA

This invention relates generally to radio frequency communication with aerospace launched vehicles during reentry descent toward earth.

BACKGROUND OF THE INVENTION

During return travel to earth, ionization of molecules occurs in the upper atmosphere adjacent to an aerospace launched reentry vehicle. The electrons and ions of oxygen and nitrogen so produced form a plasma of increasing charge density. At some point during vehicle descent, the charge density of the plasma reaches a level at which a conducting sheath is formed on the casing wall of the vehicle to reflect rf signals therefrom. Heretofore, such conducting plasma sheath caused a communication **6** blackout at distances between 100,000 and 20,000 feet above the earth's surface. Accordingly, the conducting plasma sheath is regarded by persons skilled in the art as a blackout shield detrimental to aerospace vehicle flight missions.

In an attempt to solve the communication problem involving the aforementioned conducting plasma sheath at different frequencies and power levels, travel guidance control over the reentry vehicle throughout its descent was provided by signals from a plurality of stationary satellites to maintain reentry travel along a shallow glide angle path. The conducting plasma sheath formed on the reentry vehicle as a blackout shield was thereby limited to a bottom portion thereof so that communication with one of the stationary satellites could be maintained through an antenna mounted on a vertical surface portion of the reentry vehicle at its tail end.

It is therefore an important object of the present invention to provide communication with a reentry vehicle throughout its descent without restriction or confinement of the conducting plasma sheath formed thereon, and without thereby directionally limiting communication to one source of guidance control data, as heretofore proposed in order to solve the communication blackout problem.

It is a further and related object of the invention to enable radio frequency communication with a reentry vehicle directly through the conducting plasma sheath formed thereon during descent as a result of atmospheric ionization adjacent to the casing wall of the vehicle.

SUMMARY OF THE INVENTION

In accordance with the present invention, the conducting plasma sheath formed by atmospheric ionization about a reentry vehicle during descent is modulated so as to enable transmission of radio frequency signals directly therethrough along the entire reentry path of the vehicle. Such modulation is effected by electromagnetic energy produced by a driving voltage applied to communication antennae mounted on or in close adjacency to the surface of the vehicle casing wall between its nose and tail ends. The reentry vehicle is thereby guided by signals, received during descent along a steep, non-gliding path, to assure that the modulated radiation conducting sheath is formed from plasma in complete surrounding relation to the casing wall of the reentry vehicle. According to certain embodiments of the invention, the casing wall of the vehicle may be cooled at its nose end during descent to minimize spacing of the modulated radiation conducting sheath therefrom and thereby reducing its plasma content to enhance rf signal transmission therethrough.

BRIEF DESCRIPTION OF DRAWING FIGURES

A more complete appreciation of the invention and many of its attendant advantages will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein:

FIG. **1** is a simplified partial side view of an aerospace launched reentry vehicle during descent toward the earth through its upper atmosphere;

FIG. **2** is a partial side section view through the reentry vehicle shown in FIG. **1**;

FIG. **3** is a partial section view taken substantially through a plane indicated by section line **3**—**3** in FIG. **2**;

FIG. **4** is a comparative graph of plasma sheath characteristics; and

FIG. **5** is a block diagram summarizing the method associated with the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawing in detail, FIG. **1** illustrates a reentry vehicle, generally referred to by reference numeral **10**, undergoing guided travel through the upper atmosphere along a descent path **12** toward the surface of earth **14** at relatively steep reentry angle Θ. The vehicle **10** is guided along such descent path **12** by a guidance and steering control system **16**, generally known in the art, as diagrammed in FIG. **2**. Signal inputs are supplied to system **16** from a radio frequency receiving unit **18** to which vehicle mounted antennae **20** are connected for radio frequency communication with stationary aerospace satellites, for example, as a source of descent guidance signals.

In accordance with the present invention, the antennae **20** are positioned by mounting fixtures **22** just below the outer conical surface of casing wall **24** of the vehicle **10**, between its rear tail end **26** and forward nose end **28**. Thus, the elongated elements of the antennae **20**, as shown in FIG. **2**, extend rearwardly from fixtures **22** in close spaced adjacency to the inner surface of the casing wall **24**. By virtue of such antennae arrangement, the signal receiving unit **18** is operative through system **16** to establish a non-gliding, steep descent path **12** at the reentry angle Θ for purposes of the present invention as hereinafter explained.

With continued reference to FIG. **1**, the vehicle **10** during approach to the earth **14** through the upper atmosphere causes ionization of nitrogen and oxygen molecules in the air to form a trailing plasma **30**. The charge density of the plasma so produced increases during vehicle descent to a point where an electrically conducting sheath of the plasma is formed about the casing wall **24** of the vehicle **10**. Because of the steep angle Θ of descent as aforementioned, all outer surfaces of the vehicle casing wall are completely surrounded by the conducting sheath.

It was found that the conducting plasma sheath when appropriately modulated by electromagnetic energy cooperates with the antennae **20** to receive and transmit radio frequency signals directly therethrough for appropriate exercise of communications including transmission of guidance control data. Such modulation is

effected in response to driving voltage applied to antennae **20** from unit **18** so that electromagnetic forces so generated radiate rf signals. Utilization of such signal radiating action of the plasma sheath for the entire duration of guidance controlled vehicle descent is made possible, in accordance with the present invention, because of the prolonged duration of the existence of the conducting plasma sheath during descent of the reentry vehicle. FIG. **4** graphically compares the conducting plasma sheath in terms of increasing charge density as reflected by graphically plotted line **32**, with plasma sheaths heretofore established on descending reentry vehicles along shallow glide angle paths, as reflected by plotted lines **34** and **36**. As indicated in the graph of FIG. **4**, heretofore the conducting plasma sheaths of increasing charge density reflected by plots **34** and **36** did not exist beyond a certain distance X (between 0.03 and 0.04 feet) from the vehicle casing wall as compared to the plasma sheath corresponding to plot **32**, having a conducting sheath of plasma closer to the casing wall. It is therefore contemplated that establishment of a more effective modulated plasma sheath for the entire descent duration will be assured by minimizing plasma spacing from the vehicle wall.

In accordance with certain embodiments of the invention the plasma content of the conducting sheath may be reduced by cooling of the vehicle adjacent to its nose end portion **28** during descent. Thus, as shown in FIGS. **2** and **3** a gas jet passage conduit **38** is formed at the nose end **28** of the casing wall. The passage **38** is connected by tubing **40** to a gas generator **42** within the vehicle in order to effect cooling of the vehicle wall by discharge of a jet of gas through passage **38** during vehicle descent. The amount of plasma in the conducting sheath is thereby minimized while maintaining its shape in surrounding relation to the vehicle wall **24** in order to maximize the RF radiation transmission property produced by plasma modulation.

The method associated with the present invention as hereinbefore described is summarized by reference to the block diagram of FIG. **5**, wherein the RF signal antennae **20** are depicted as receiving a plasma modulating voltage **44** from unit **18** for application to the plasma sheath **46**. Establishment of the plasma sheath **46** in complete surrounding relation to the casing wall **24** is assured by guidance of the vehicle **10** along its path **12** at the steep descent angle Θ, as denoted in FIG. **5** by block **48**. Such guidance occurs in response to RF signal input received by the antennae **20** through the conducting plasma sheath **46** during RF signal communication established therethrough for the duration of vehicle descent, as also depicted in FIG. **5** by block **50**.

Obviously, other modifications and variations of the present invention may be possible in light of the foregoing teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In combination with an aerospace launched vehicle undergoing travel toward earth to produce a sheath of plasma of increasing charge density by ionization of atmosphere surrounding the vehicle between nose and tail ends thereof, said vehicle having a casing wall enclosing control means for guiding said travel along a descent path at a reentry angle to the earth and antenna means operatively connected to the control means for supply of guidance data thereto in response to receipt of radiation signals, the improvement residing in: mounting means positioning the antenna means in close adjacency to the casing wall for receiving the radiation signals through the sheath on the casing wall during said travel of the vehicle and

means cooling the nose end of the vehicle for minimizing spacing of the plasma in the sheath from the casing wall.

2. The improvement as defined in claim **1** wherein and said cooling means includes a gas generator and conduit means connected to the gas generator and extending through the nose end of the vehicle for discharge of a jet of cooling gas therefrom.

3. The combination of claim **2** wherein said reentry angle of the descent path is relatively steep to assure establishment of the sheath in complete surrounding relation to the casing wall during said travel of the vehicle.

4. The combination of claim **1** wherein said reentry angle of the descent path is relatively steep to assure establishment of the sheath in complete surrounding relation to the casing wall during said travel of the vehicle.

5. In combination with an aerospace launched vehicle undergoing descent toward earth to produce plasma of increasing charge density by ionization of surrounding atmosphere, said vehicle having a nose end and a casing wall extending therefrom on which antenna means is mounted for reception of radiation signals, a method for enhancing communication with the vehicle through said antenna means, including the steps of: applying electromagnetic energy through the antenna means to the plasma for modulation thereof into a radiation conducting sheath extending from said nose end about the casing wall; transmitting the radiation signals directly through the modulated plasma of the radiation conducting sheath for said reception thereof by the antenna means to guide said descent of the vehicle and cooling the vehicle during said descent thereof for minimizing content of the plasma in the radiation conducting sheath extending from the nose end of the vehicle.

6. The method as defined in claim **5** wherein the descent of the vehicle is guided along a relatively steep reentry angle path establishing the radiation conducting sheath in complete surrounding relation to the casing wall during said descent of the vehicle.

7. The method as defined in claim **6** wherein said step of cooling the vehicle comprises discharge of a jet of coolant from the nose end of the vehicle to minimize spacing of the radiation conducting sheath from the casing wall.

8. The method as defined in claim **5** wherein said step of cooling the vehicle comprises discharge of a jet of coolant from the nose end of the vehicle to minimize spacing of the radiation conducting sheath from the casing wall.

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